Nutrient Targets for Development of Biologically Based Total Maximum Daily Loads for the Upper Midwest

U.S. EPA Nutrient TMDL Workshop

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Nutrient Impairment in Indiana's Rivers

- Nutrients fifth cause of impairments in rivers
- 749 stream miles listed as impaired for nutrients

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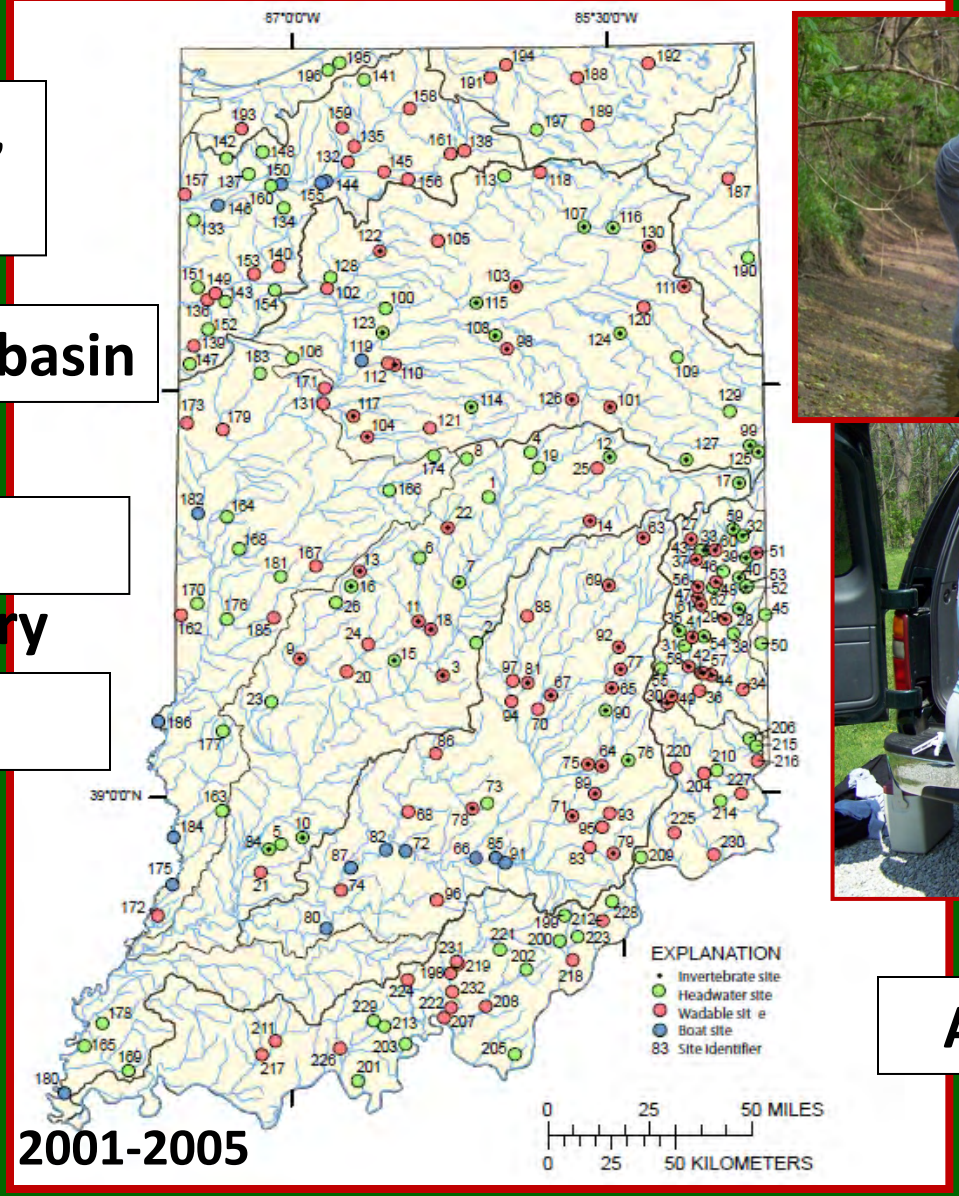
Indiana's Nutrient Monitoring Strategy

Rotating basin, probabilistic

34- 38 sites/basin

Water chemistry

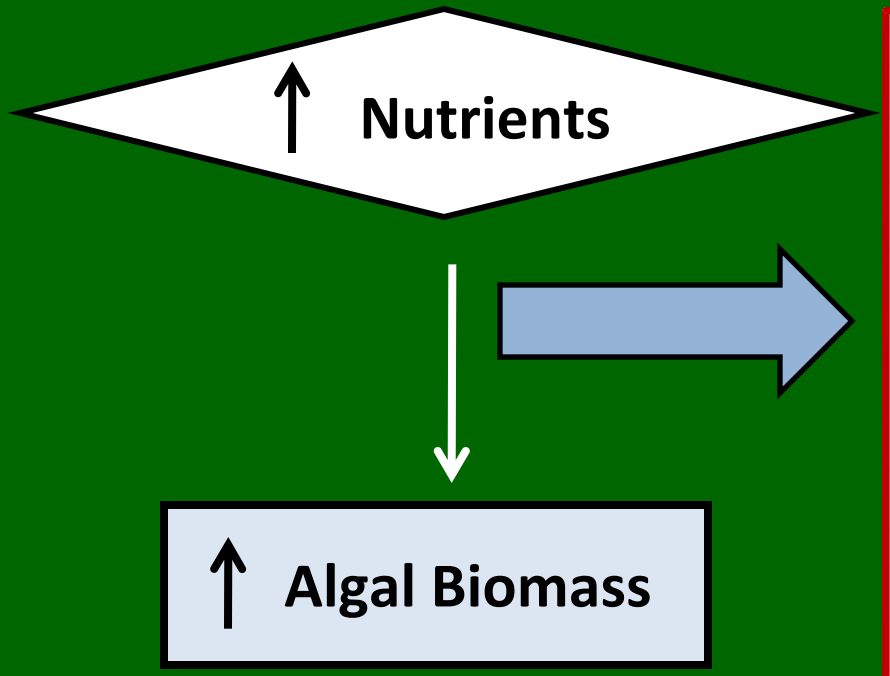
Fish, inverts

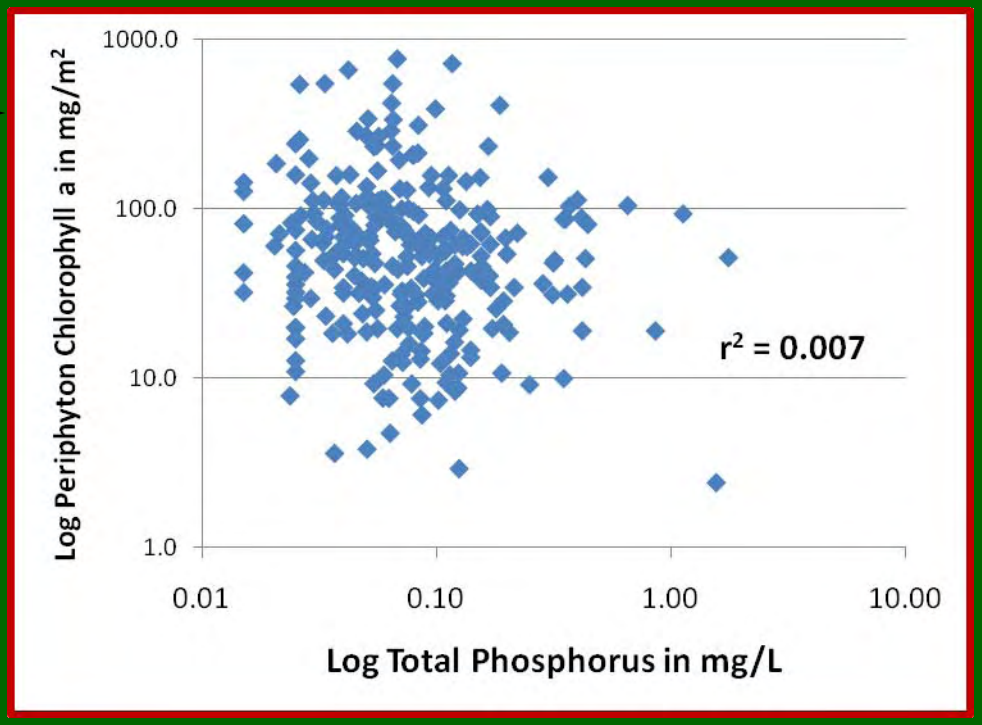


2001-2005

Algal biomass

Past Nutrient Criteria Development Efforts





Suggests biological community response needs to be incorporated into criteria development

Recent Nutrient Criteria Development Efforts

Using 2001-2005 Indiana data, determine:

- Statistically and ecologically significant relationships between:
  stressor (TN, TP, chl *a*, and turbidity) and response variables (biological community)
- Breakpoints of biological community attributes in response to changes in stressor variables

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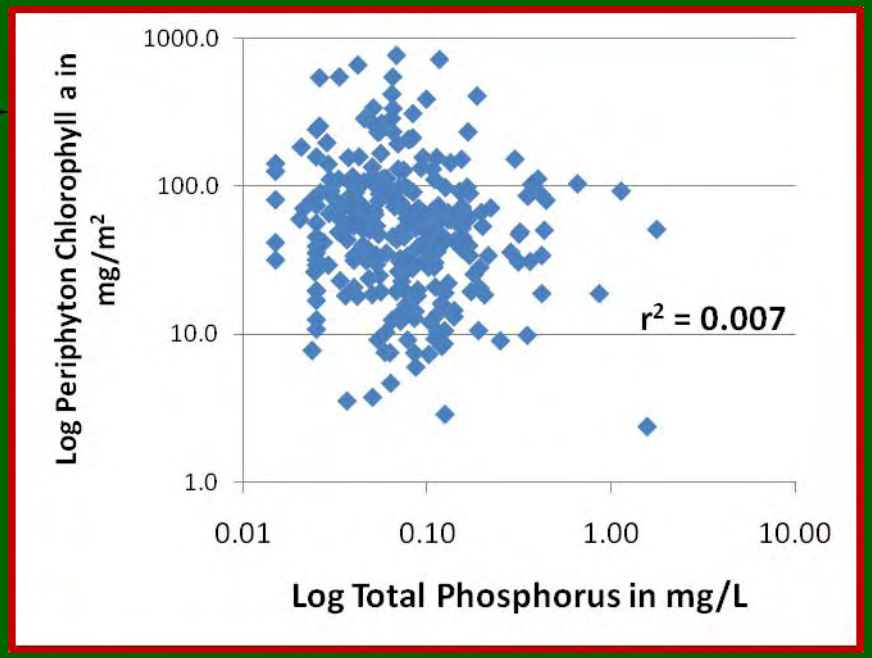
Conceptual Approach

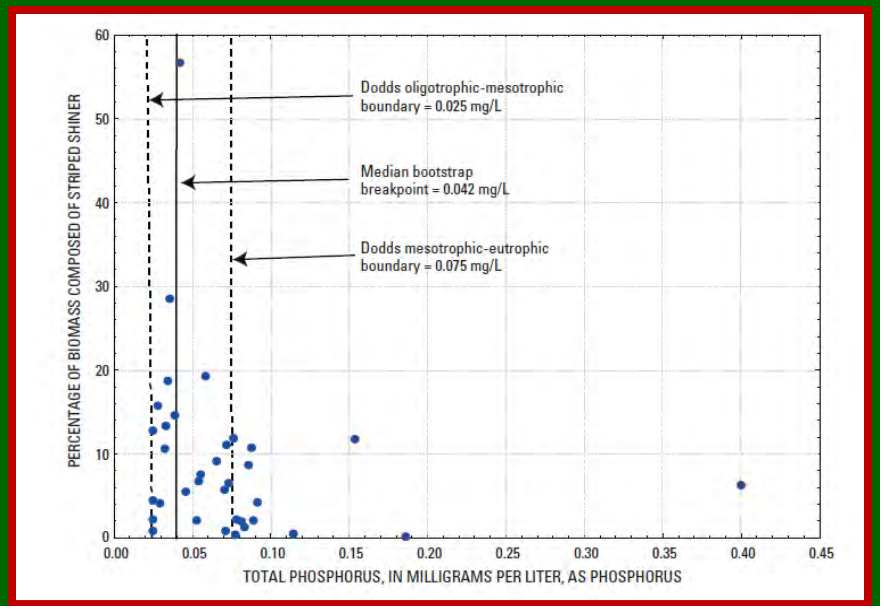
↑ Nutrients

↑ Algal Biomass

↓ Sensitive Species
↓ Taxa Richness
↑ Tolerant Species
↑ Omnivores

↓ Biological Condition



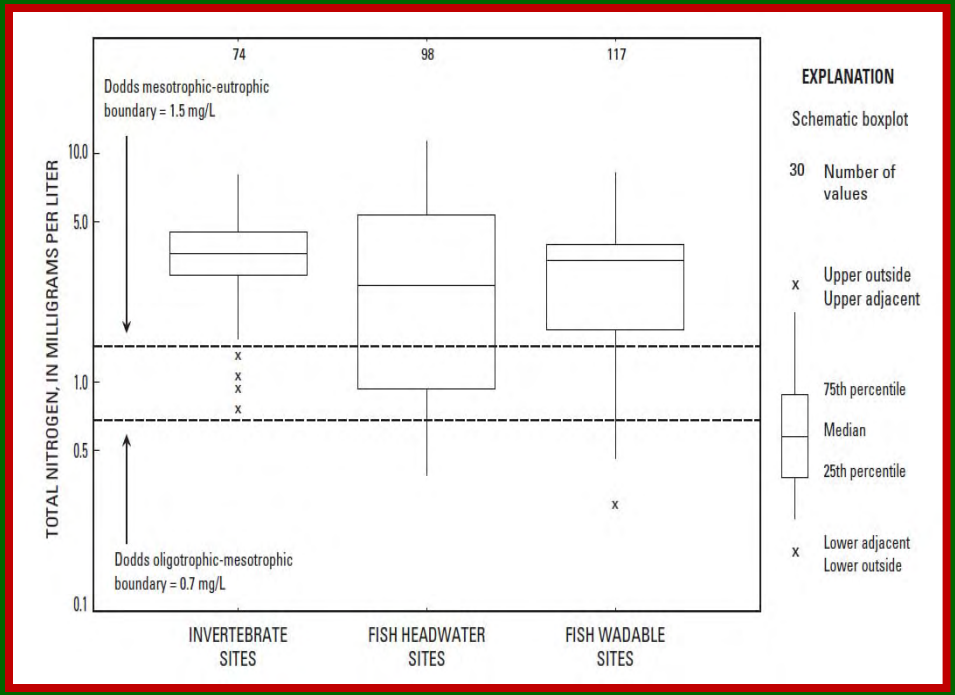


Data Analysis

- **Determine if natural variability required data to be subset**
- **Stressor variables:**
  - **examined for distribution**
  - **examined for correlations with each other**
  - **compared to Dodds' trophic classification levels**
- **Assess biological communities to determine:**
  - **if species composition reflect nutrient-enriched conditions**
  - **where breakpoints in biological community attributes occurred in response to stressor variables**

Results Indicate Elevated Nutrients and Eutrophic Biological Communities

- **Concentration ranges:**
  - **TN: 0.30 - 11 mg/L**
  - **TP: 0.025 - 1.33 mg/L**
  - **Chl *a:* 1 - 1,200 mg/m²**
  - **Turbidity: 0.8 – 65.4 NTU**



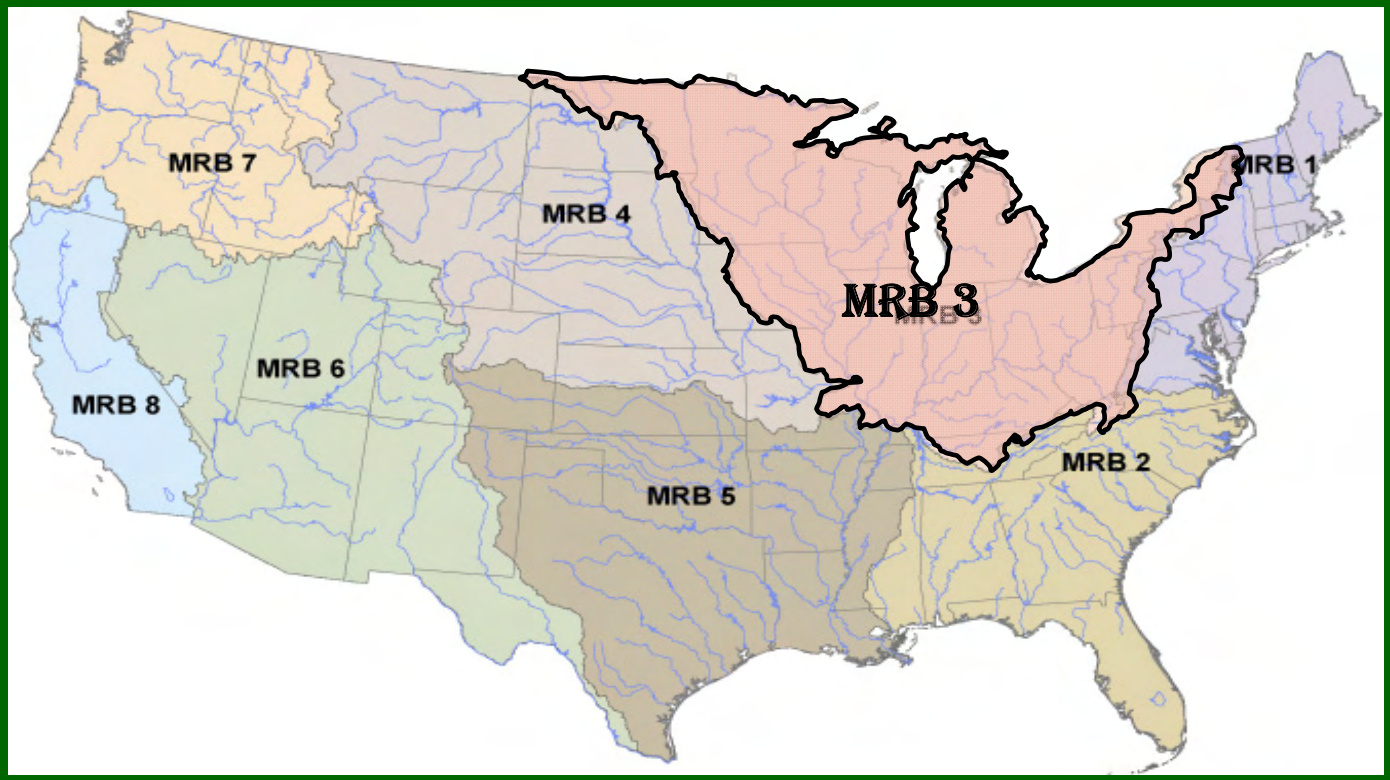
- **Relative total abundance of inverts dominated by:**
  Chironomidae, Hydropsychidae, and Baetidae
- **Fish communities dominated by:**
  central stonerollers, creek chubs, and bluntnose minnows

Example of Breakpoint Results

Data site type	Biological response variable	Stressor variable to biological attribute Spearman rho	n	Median bootstrap breakpoint	Bootstrap confidence interval
		TN (mg/L)			
Invertebrate	Hydroptilidae (percent relative abundance)	0.337	40	3.3	2.3–4.0
Fish headwater	White sucker (percentage of biomass)	.316	50	2.9	2.8–5.9
Fish wadable	Number of pioneer taxa	.314	114	2.4	2.0–4.0
		TP (mg/L)			
Invertebrate	Percentage of abundance composed of molluscs and crustaceans	0.422	38	0.090	0.057–0.110
Fish headwater	Striped shiner (percentage of biomass)	-.337	34	.042	.042–.077
Fish wadable	Green sunfish (percent relative abundance)	.296	88	.129	.099–.176

[n, number of sites in analysis; TN, total nitrogen; mg/L, milligrams per liter; TP, total phosphorus; CHL*a*, chlorophyll *a*; mg/m², milligrams per square meter; µg/L, micrograms per liter; NTU, Nephelometric turbidity units]

USGS Major River Basin 3 Corresponds to USEPA Nutrient Ecoregions



- One of 8 Major River Basins in the US
- Similar to: USEPA Region V and Nutrient Ecoregions VI, VII, VIII

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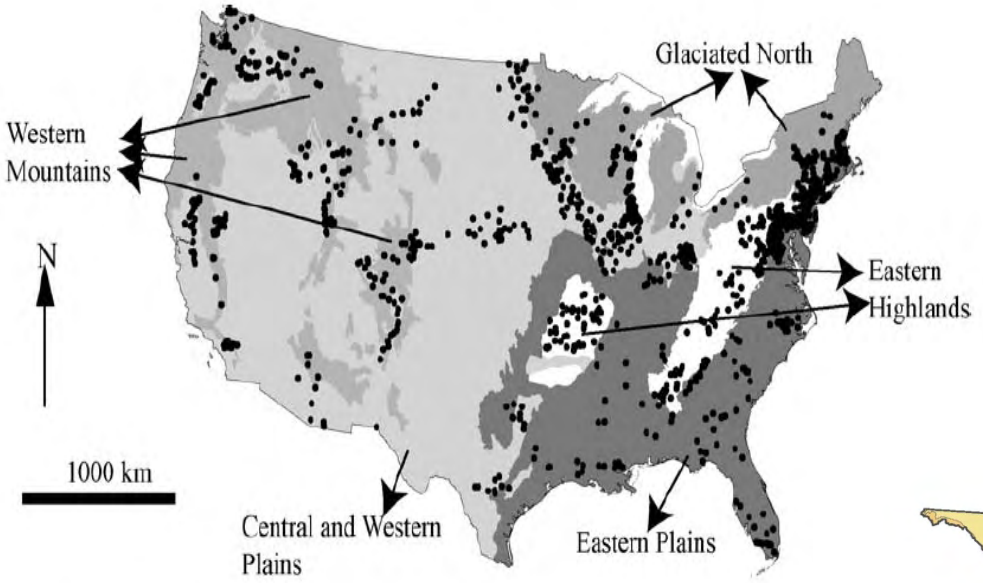
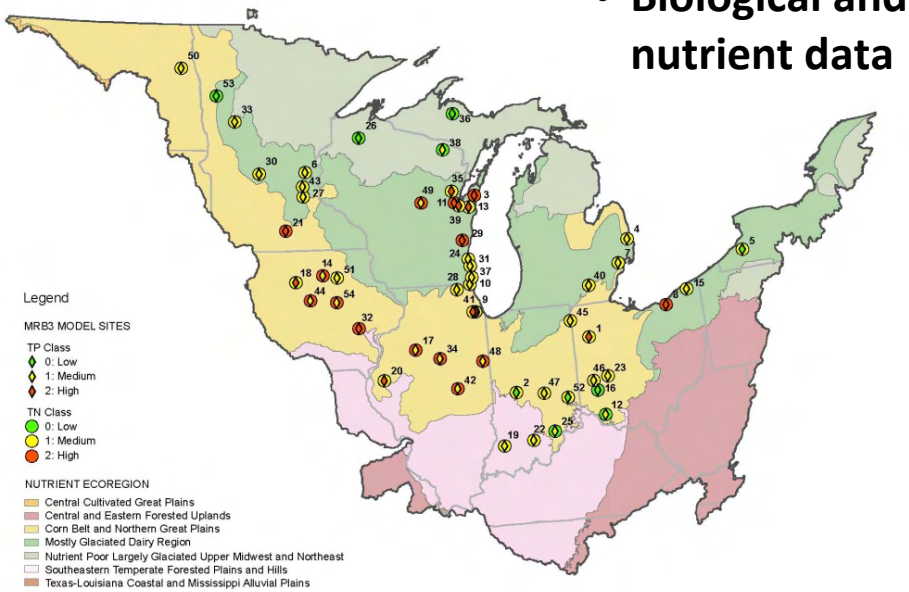
Study Area Corresponds to Diatom Ecoregions



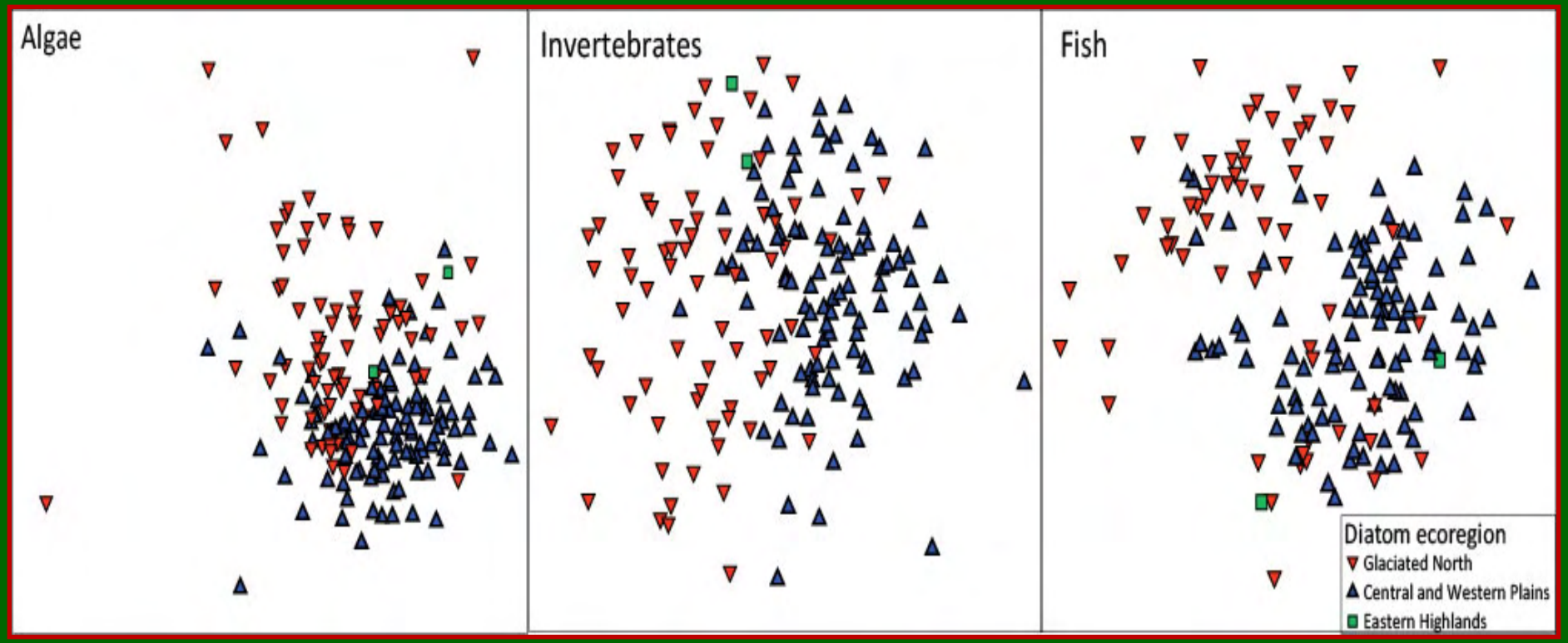
Follows Potapova's Diatom Ecoregions

(Potapova and Charles, 2007)

- **n = 54**
- **Biological and nutrient data**



Biological Communities Differed Significantly in the Two Diatom Ecoregions



Multidimensional Scaling Analysis

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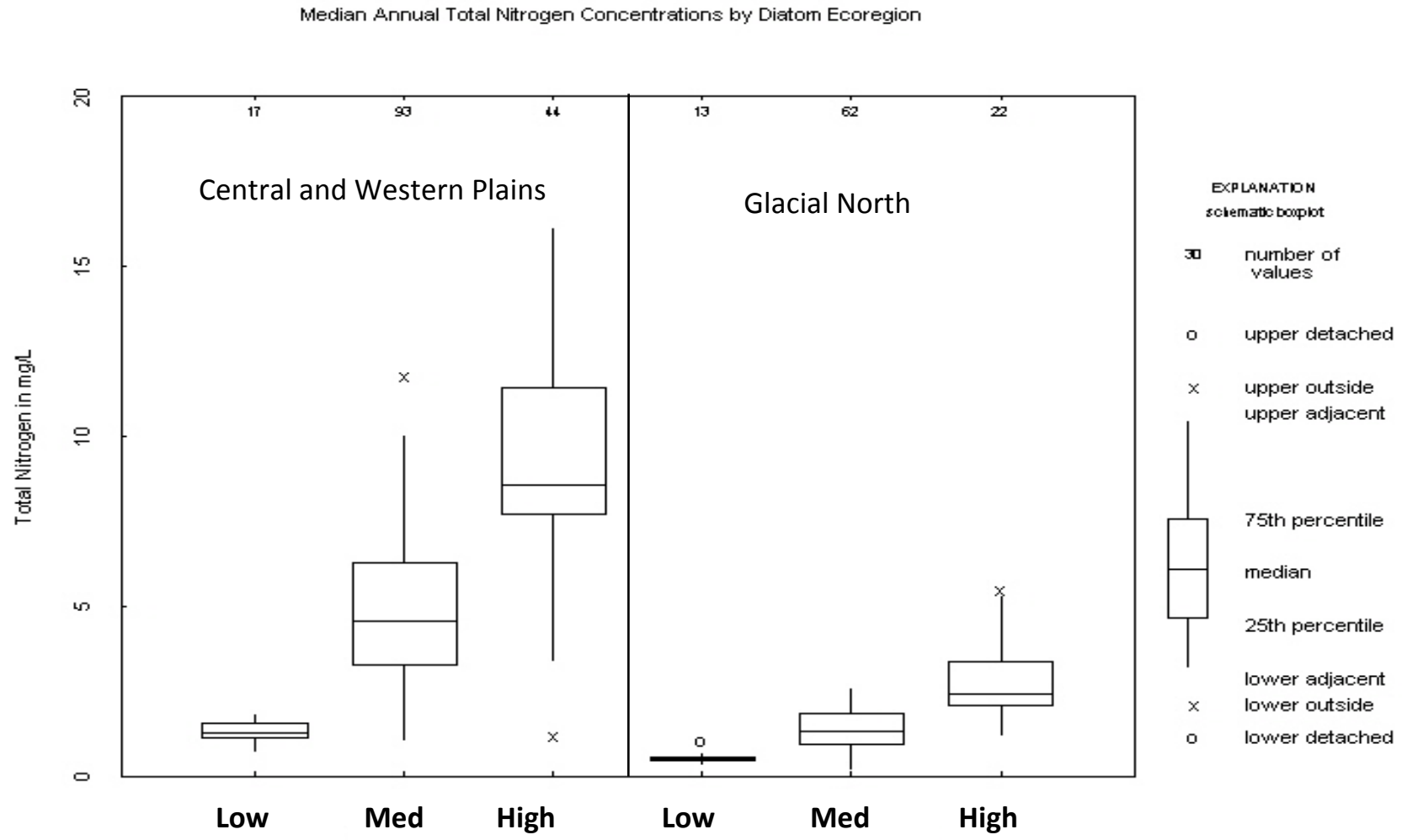
Sites Classified into Nutrient Categories

Based on 10th and 75th Percentiles

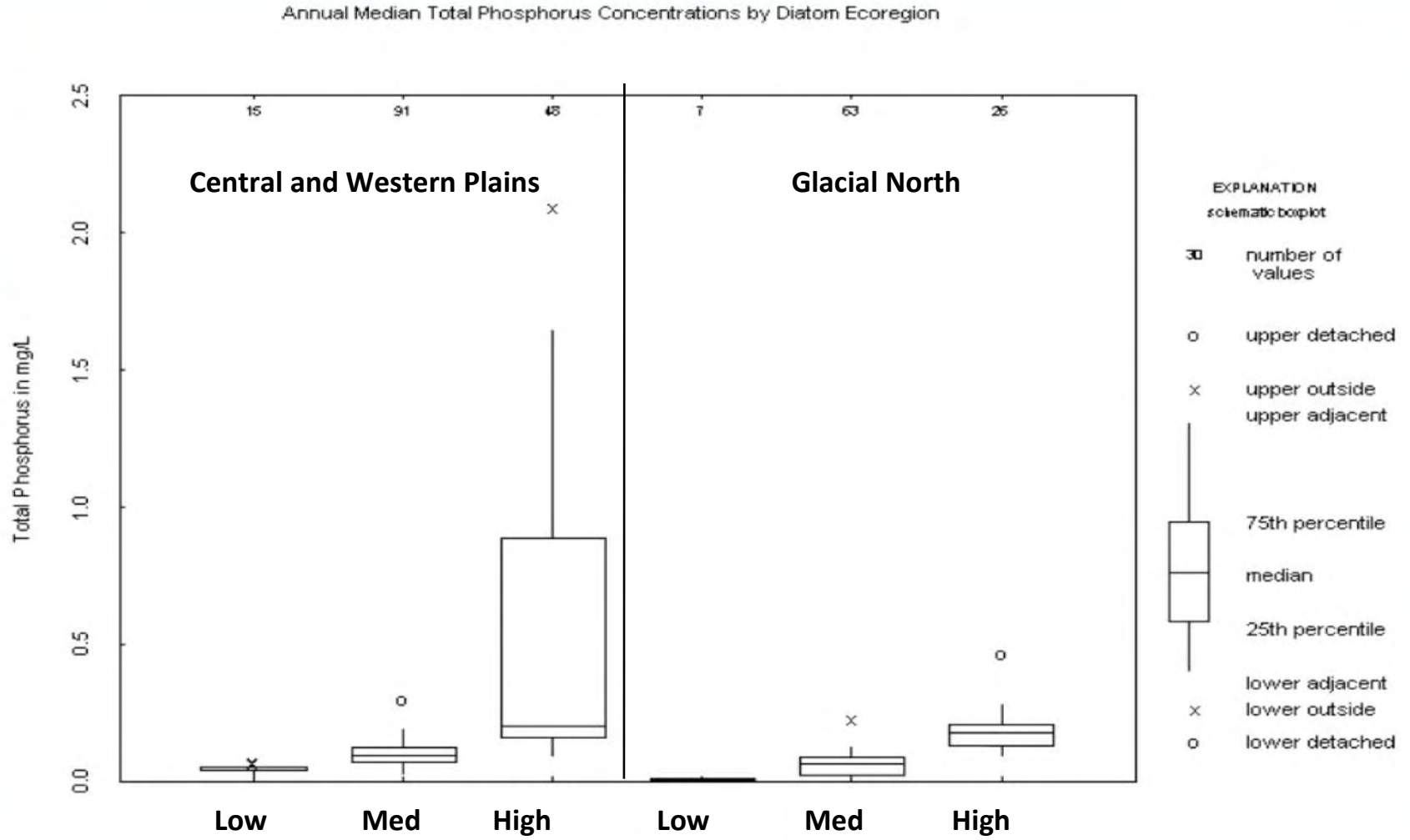
Nutrient	Nutrient Class		
	Low Sites	Medium Sites	High Sites
Central and Western Plains Diatom Ecoregion (31 sites)			
Total Nitrogen (mg/L)	< 1.74	1.74 - 7.80	> 7.80
Total Phosphorus (mg/L)	< 0.05	0.05 - 0.17	> 0.17
Glaciated North Diatom Ecoregion (23 sites)			
Total Nitrogen (mg/L)	< 0.60	0.60 - 2.08	> 2.08
Total Phosphorus (mg/L)	< 0.01	0.01 - 0.13	> 0.13

TN 3-5 Times Greater in CWPE than in GNE



Results

TP 3-5 Times Greater in CWPE than in GNE



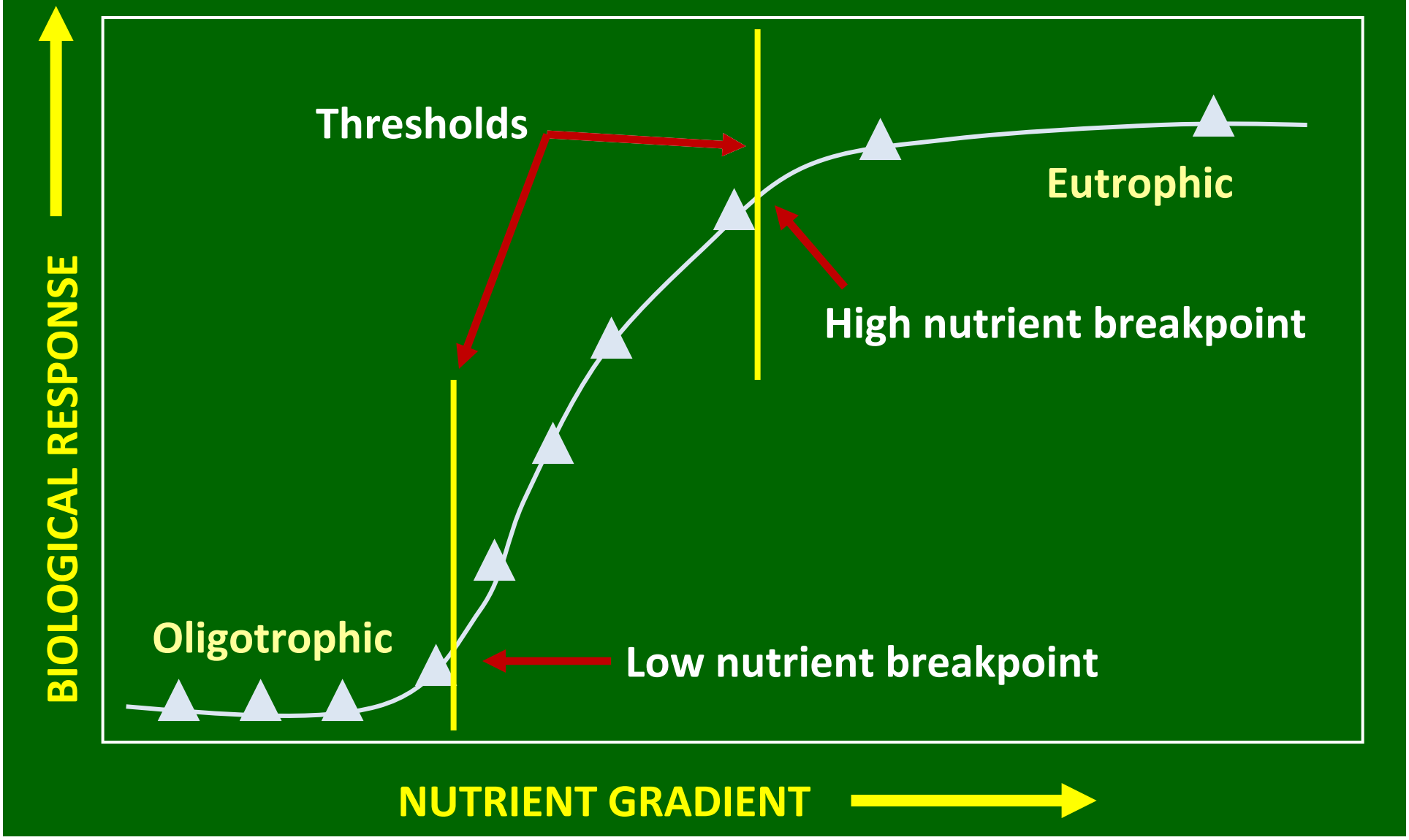
Results

Species Composition Differed Between Nutrient Categories

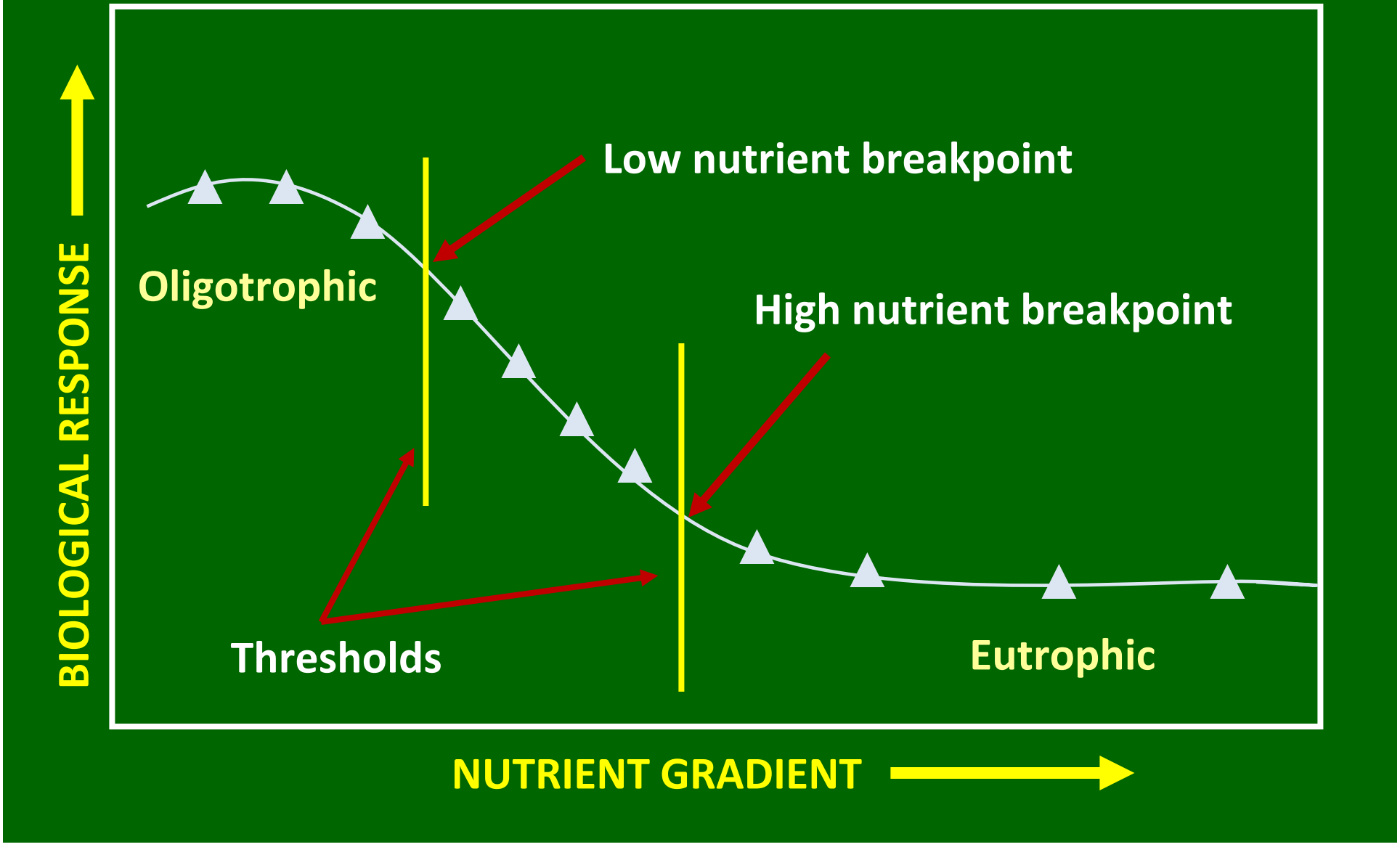
Central and Western Plains Ecoregion - Total Phosphorus					
Low Sites (<0.05 mg/L) (n=13)		Medium Sites (>0.05 - <0.17 mg/L) (n=61)		High Sites (> 0.17 mg/L) (n=30)	
Species	Mean	Species	Mean	Species	Mean
central stoneroller	21.25	spotfin shiner	8.76	spotfin shiner	15.00
bluntnose minnow	12.14	bluntnose minnow	8.03	bluntnose minnow	13.10
creek chub	11.83	sand shiner	5.92	sand shiner	10.80
common shiner	6.30	green sunfish	5.76	green sunfish	9.82
sand shiner	4.76	white sucker	5.36	bluegill	6.26
blacknose dace	4.04	central stoneroller	5.09	fathead minnow	5.63
hornyhead chub	3.10	creek chub	4.26	common carp	4.87
striped shiner	2.82	golden redhorse	3.90	white sucker	2.64
black redhorse	2.49	bluegill	2.78	yellow bullhead	2.35
northern hog sucker	2.33	northern hog sucker	2.68	creek chub	2.06

Glacial North Ecoregion - Total Phosphorus					
Low Sites (<0.01 mg/L) (n=8)		Medium Sites (>0.01 - <0.13 mg/L) (n=47)		High Sites (> 0.13 mg/L) (n=20)	
Species	Mean	Species	Mean	Species	Mean
mottled sculpin	19.42	common shiner	11.23	johnny darter	27.66
longnose dace	12.93	white sucker	10.76	creek chub	11.58
brown trout	10.56	creek chub	6.65	central mudminnow	6.28
freshwater sculpins	10.72	hornyhead chub	5.48	white sucker	6.20
blacknose dace	7.94	bigmouth shiner	5.41	brook stickleback	5.76
creek chub	5.02	fathead minnow	5.29	common shiner	5.71
white sucker	2.89	bluntnose minnow	4.35	blacknose dace	3.78
burbot	2.28	rock bass	4.00	blackside darter	3.42

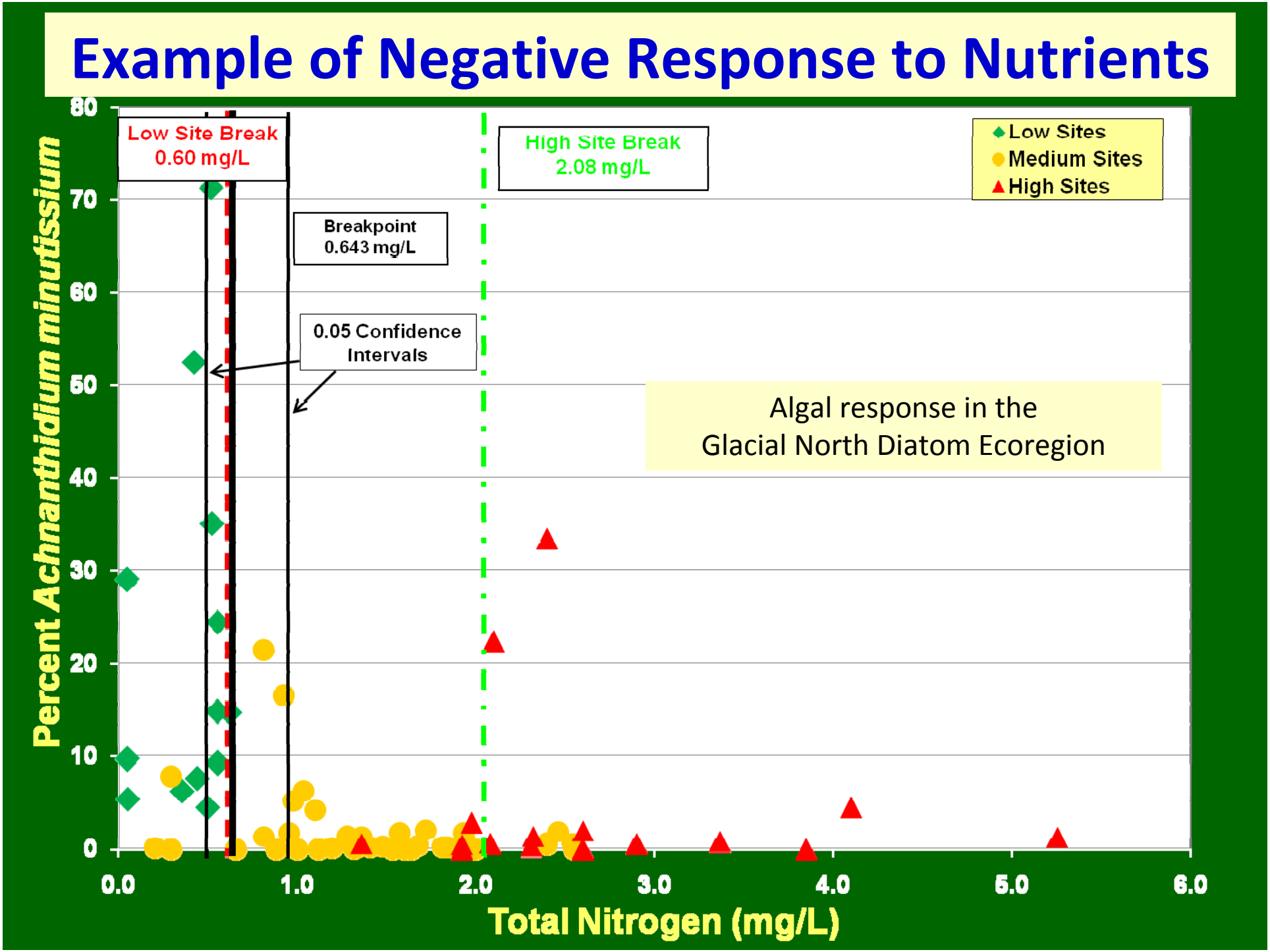
A Conceptual Model:
Positive Biological Response to Nutrients



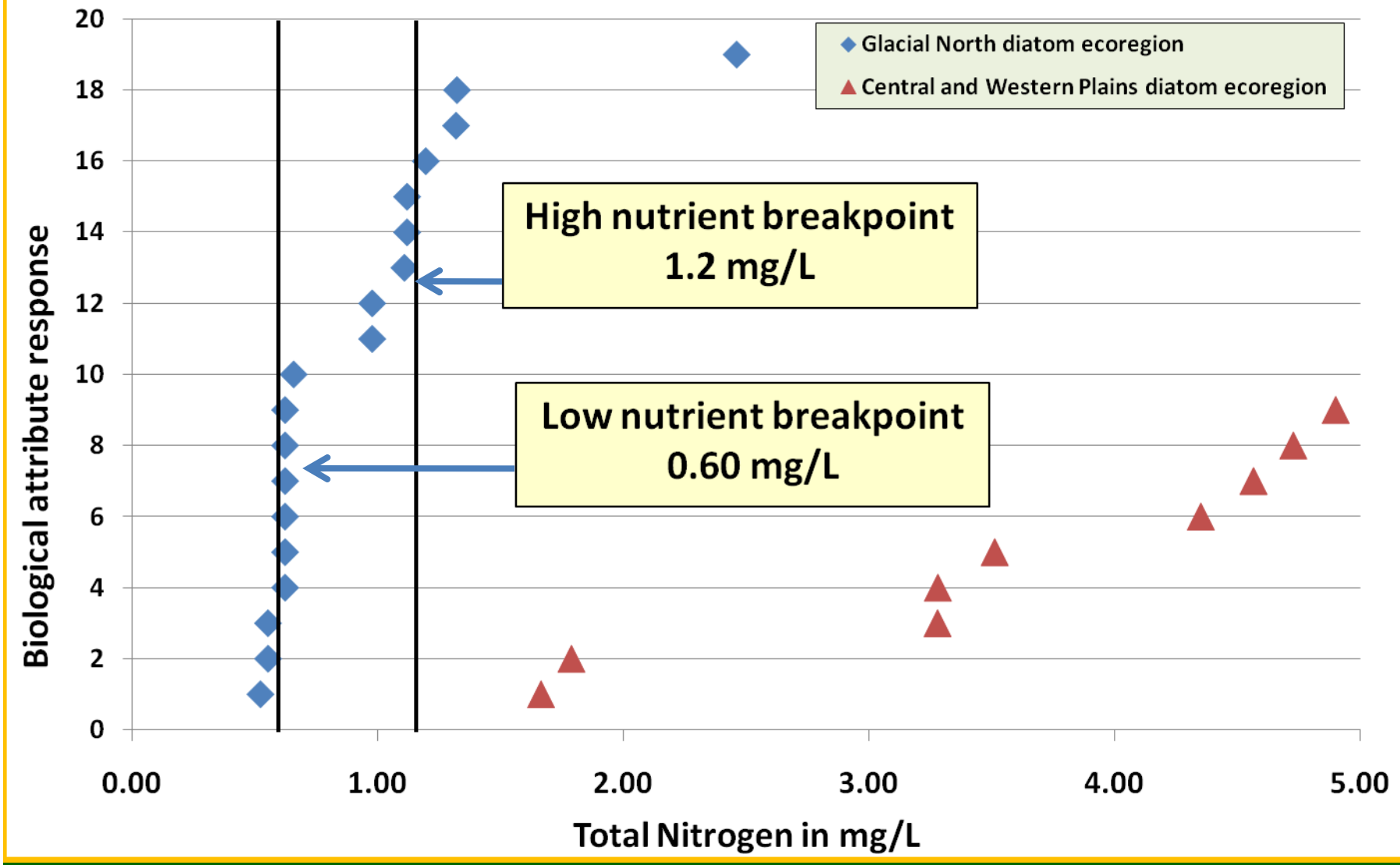
A Conceptual Model:
Negative Biological Response to Nutrients



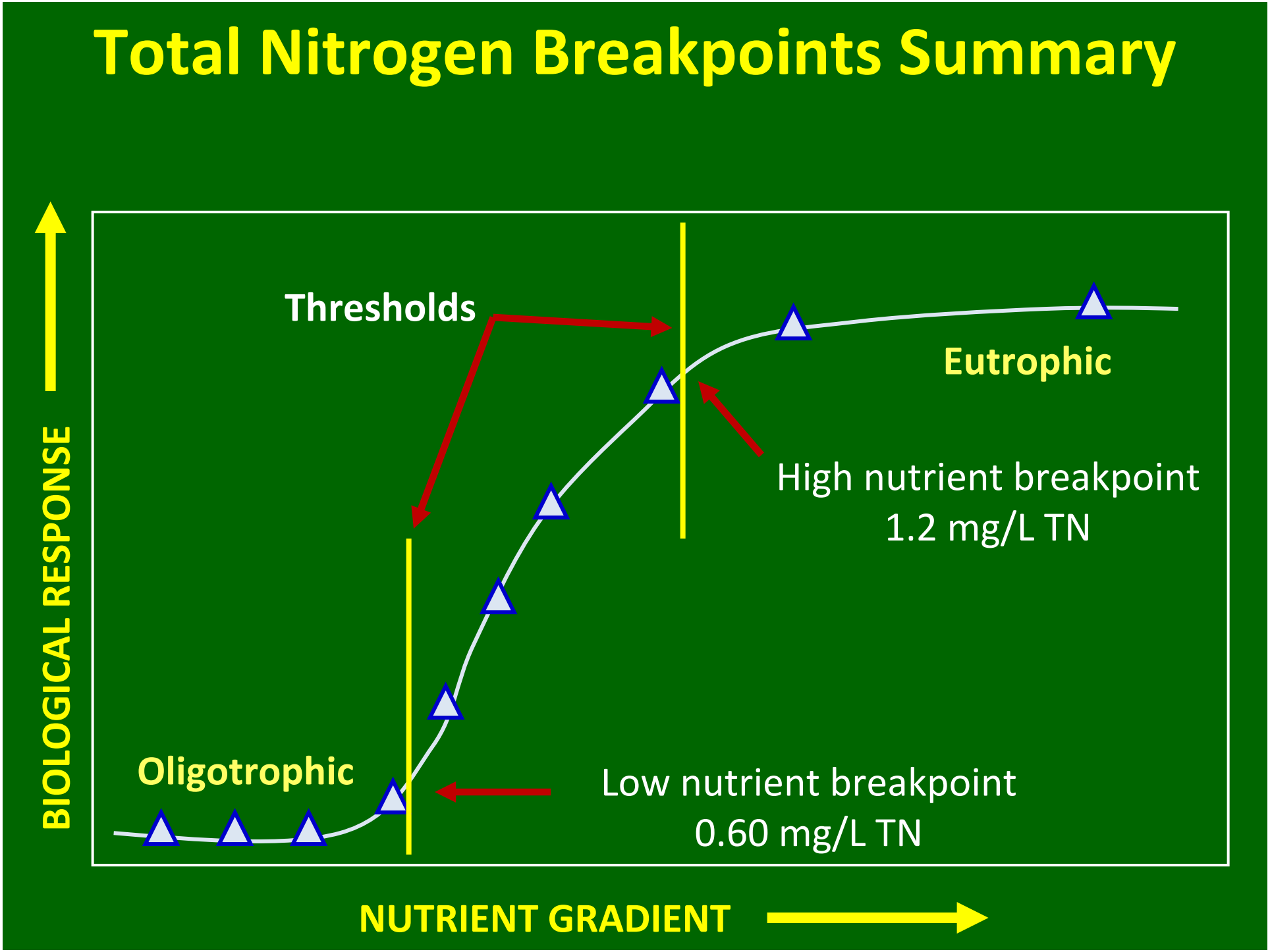
Example of Negative Response to Nutrients



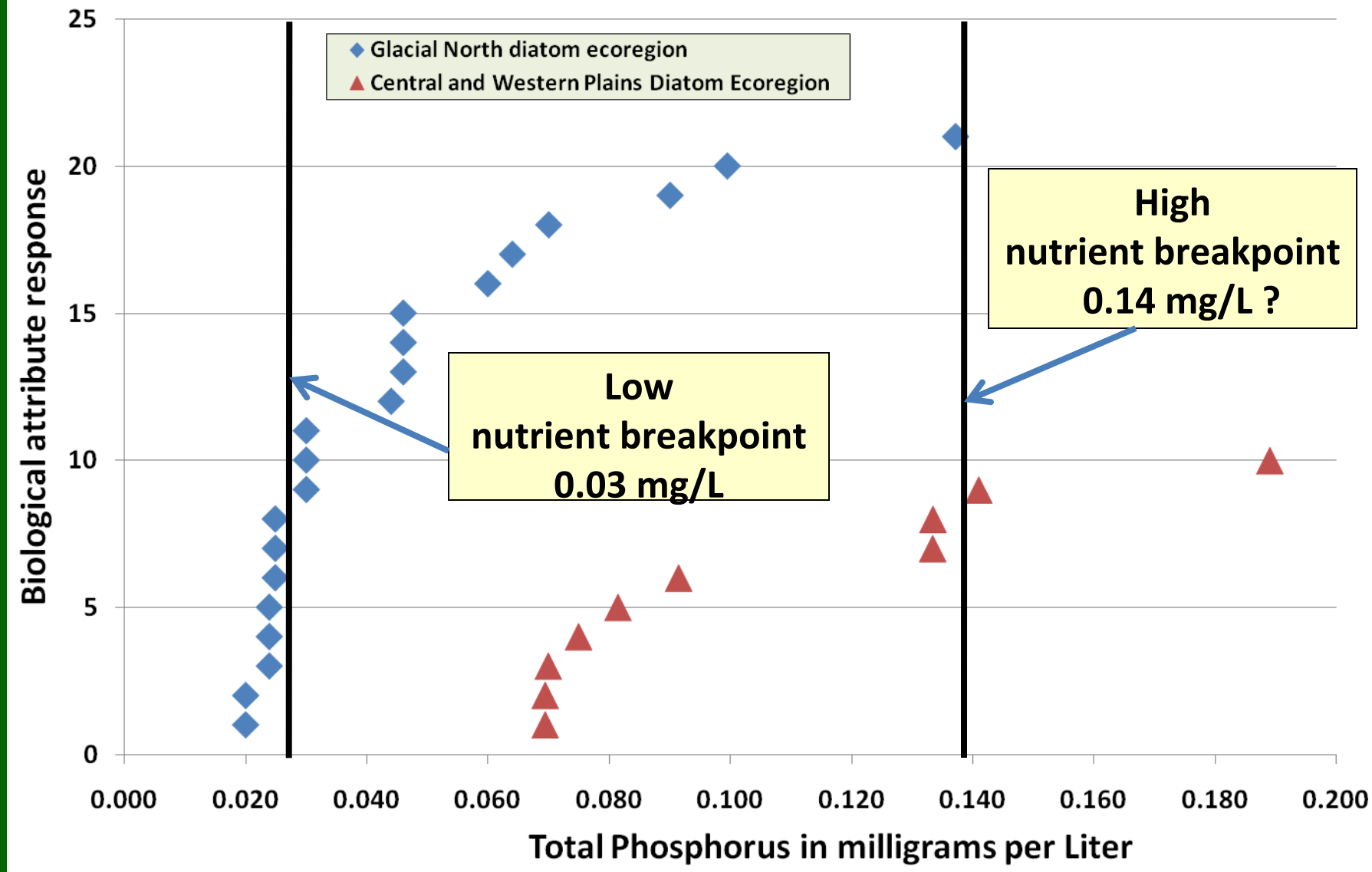
Total Nitrogen Breakpoints Differed by Ecoregion



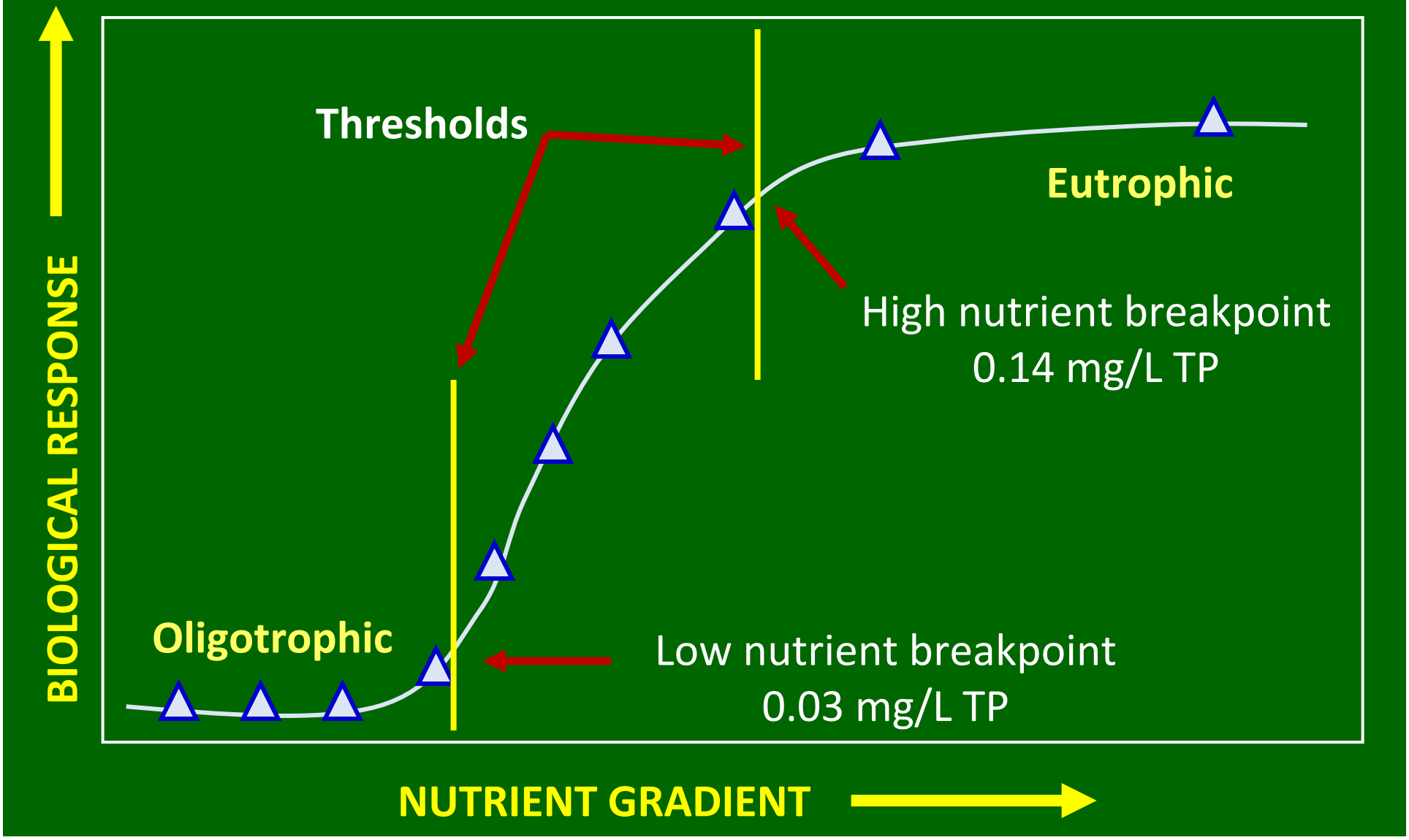
Total Nitrogen Breakpoints Summary



Total Phosphorus Breakpoints Differed by Ecoregion



Total Phosphorus Breakpoints Summary



Breakpoint Summary by Ecoregion

Glacial North Diatom Ecoregion	Trophic Level Indicator	Central and Western Plains Diatom Ecoregion
Sufficiently low nutrient concentrations	Nutrient gradient	Nutrient saturated
Reflect all trophic levels	Biological communities	Reflect nutrient saturation
Oligotrophic conditions identified	Biological breakpoints	No low nutrient breakpoints identified
More	Statistically significant breakpoints	Fewer
More	Ecologically significant breakpoints	Fewer
Low nutrient breakpoints (oligotrophic)		
TN: < 0.60 mg/L		None
TP: < 0.035 mg/L		None
High nutrient breakpoints (eutrophic)		
TN: > 1.2 mg/L		TN: > 1.7 mg/L
TP: > 0.14 mg/L		TP: > 0.13 mg/L

Comparison of MRB3 Biological Breakpoints to Other Studies

		Biological Response			
		TN (mg/L)		TP (mg/L)	
Study	Location	Low	High	Low	High
Smith Nutrient IBI (2007)	New York	0.34	1.40	0.018	0.065
NEET O/E	Midwest	0.58	1.34	0.026	0.100
Crain and Caskey (2010)	Kentucky wadable	--	--	0.032	--
Miltner (2010)	Ohio	--	--	0.038	--
Heiskary et al (2010)	Minnesota (North and Northwest)	--	1.77	0.040	
Robertson et al (2008)	Wisconsin (large rivers) inverts	0.53	1.99	0.040	0.150
Robertson et al (2006)	Wisconsin (wadable streams) fish	0.54	--	0.055	0.067
Frey et al (2011) wadable	Glacial North (MN, WI, MI)	0.60	1.20	0.030	0.100
NEET EPT richness	Midwest, West	0.60	--	0.052	0.174
Wang et al (2007)	Wisconsin	0.60	--	--	--
Miltner and Rankin (1998)	Ohio	0.61	1.65	0.060	0.170
Robertson et al (2006)	Wisconsin (wadable streams) inverts	0.61	1.11	0.088	0.091
Robertson et al (2008)	Wisconsin (large rivers) fish	0.63	1.97	0.079	0.139
Caskey et al (2010)	Indiana wadable	2.40	3.30	0.042	0.129
Heiskary et al (2010)	Minnesota (south)	1.77	3.60		
Frey et al (2011)	Central and Western Plains (IL, IN, OH)	1.70	3.50	0.075	0.133
	Background nutrient concentrations or trophic levels				
Dodds et al (1998)	National, 33rd and 66th percentiles	0.70	1.70	0.025	0.075
Robertson et al (2006)	Wisconsin (median reference) wadable	0.61	1.10	0.035	--
Robertson et al (2008)	Wisconsin (median reference) large rivers	0.40	0.70	0.035	--

Next Steps

Analysis of 2005-2009 nutrient data

- **Differences in biological measures (species and attributes)**
  - **Determine breakpoints for causal variables (TN, TP, chl *a*) based on changes in the biological measures along a causal variable gradient**

    Spearman correlation: initial examination of relationships among TP, TN, chl *a*, and biological metrics

    Change point, Quantile Regression, TITAN analysis: identify biological threshold responses to nutrient concentrations

- **Possible Use of GNE breakpoints as protective limits**

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